Experimental Study of the μ^- Meson Mass and the Vacuum Polarization in Mesonic Atoms*

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Studies of the x-rays emitted in transitions of mesons between atomic orbits about nuclei have been extended(1) to 3D-2P and 4F-3D transitions in a variety of elements for both π^- and μ^- mesons. Particular attention has been paid to μ^- mesonic transitions having energies below 90 Kev, using thin filters between the anticoincidence counter and the NaI crystal of the scintillation spectrometer.(2) Because of the large and rapid change in absorption cross section at the photoelectric "K edge" energy and the precise knowledge of these energies,(3) it is possible to state whether a particular mesonic x-ray lies above or below the "K edge" of a given filter element and thus place an upper or lower limit on the energy of that transition. Calculated mesonic x-ray energies in this energy range are only slightly affected by readily evaluated nuclear size corrections; other effects(4), except for the vacuum polarization, are considered negligible. A large number of such transitions have been studied to date. The observed pulse height spectra contain components

of degraded radiation arising from Compton scattering in the meson target and surrounding material and flourescent radiation from the filter. Thus the upper energy part of the pulse height distribution is emphasized in the interpretation of the data.

At present, the results of most interest in the determination of the μ^- meson mass and of vacuum polarization effects are the following. For the 2P-1S transition in carbon, Z = 77, 78, 79 filters all behave similarly indicating "K edges" above the mesonic x-ray energy while Z = 74 has its "K edge" well below the mesonic energy. The Z = 77 filter indicates that the transition energy is below 76.123 Kev. The most significant result was that the phosphorus 3D-2P transition energy lies above the Z = 81 and 82 absorption edges and below the Z = 83 edge. Corresponding to the Z = 82 absorption edge we emphasize that the photon energy in this case is greater than 88.065 Kev. The 4F-3D transition in silicon indicates that the transition energy is above the Z = 47 and 48 absorption edges and below that for Z = 49, corresponding to a transition energy greater than 26.713 Kev for the Z = 48 edge.

The lowest order vacuum polarization effect, as given by the Uehling integral[5], has been evaluated for these states by two independent approximate methods which agree to within 2 percent. The effect always increases the binding energy. This amounted to 0.40 percent, 0.099 percent, 0.25 percent, 0.103 percent, 0.094 percent and 0.034 percent for the 1S and 2P levels in

carbon, the 2P and 3D levels in phosphorus, and the 3D and 4F levels in silicon respectively. Table I lists the corresponding upper or lower limits on the μ^- meson mass before and after applying the vacuum polarization correction. The Dirac formula for a point nucleus was used and a nuclear size correction was needed only for the 1S level of carbon (decreases binding energy 0.45 percent).

The latest reported value of the μ^- meson mass, measured by independent means,[6] is 206.9 $\pm$ .2 electron mass units.[7] The stated uncertainty does not include estimates of possible systematic errors which could be of comparable amount. We therefore conclude that an effect of the order of magnitude of the vacuum polarization is necessary for agreement with the lower limit for the meson mass (3D-2P transition in phosphorus with Z = 82 filter) measured here.

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TABLE I

Upper or lower limits on the μ^- meson mass/electron mass without and with vacuum polarization correction.

Transition		without V_p	with V_p
C: 2P-1S	less than	209.99	208.95
P: 3D-2P	greater than	207.67	206.89
Si: 4F-3D	greater than	206.82	206.47

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